MACHINABILITY

THE MACHINABILITY OF CARBON AND ALLOY STEELS is affected by many factors, such as the

- composition
- microstructure
- strength of the steel
- the feeds
- speeds
- depth of cut
- the choice of cutting fluid
- cutting tool material

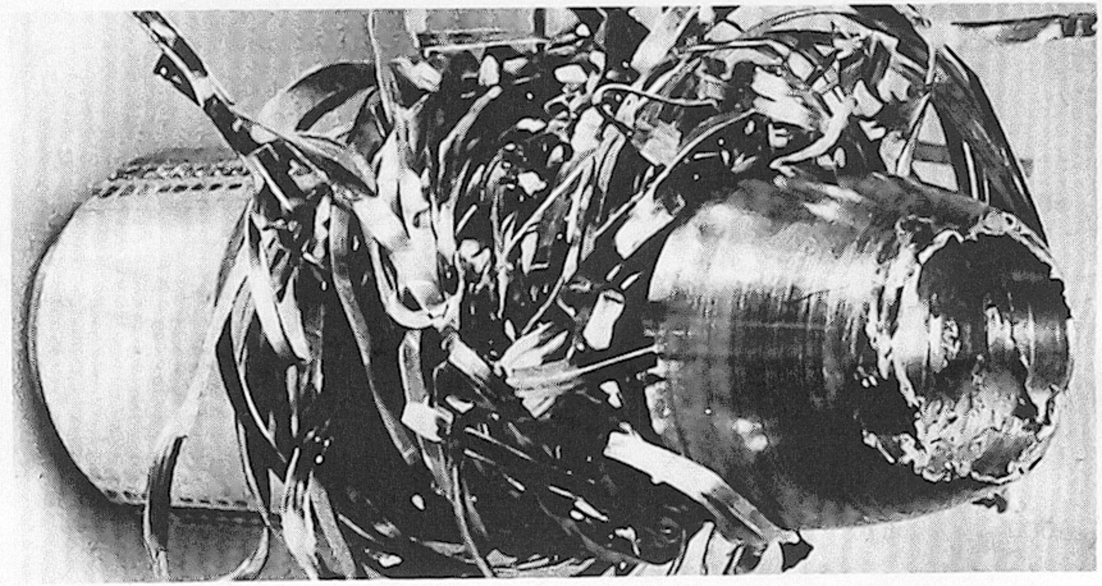
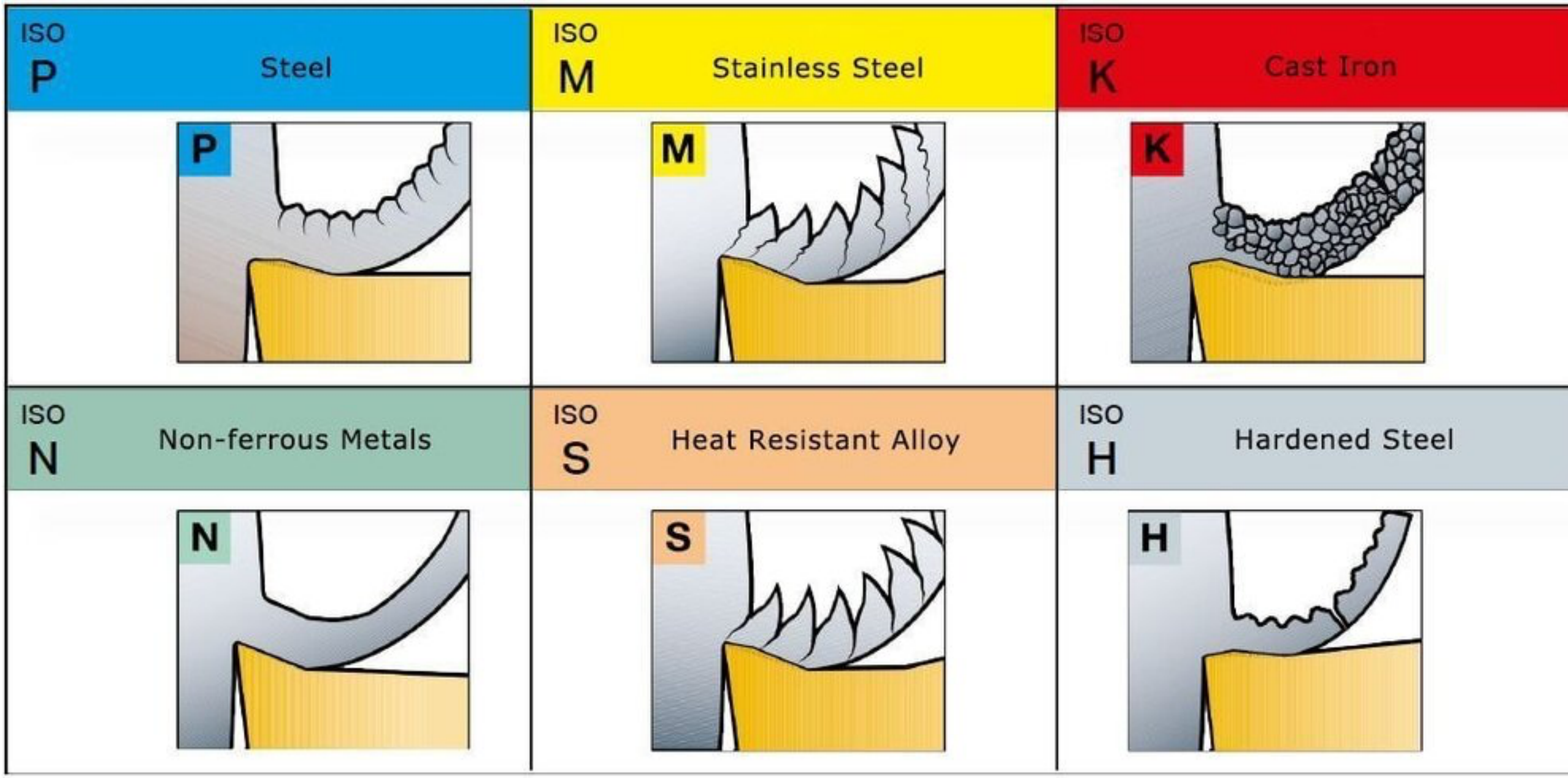


FIGURE 8 The consequences of poor or non-existent chip breaking.

These machining characteristics, in turn, affect the cost of producing steel parts, particularly when the cost of machining represents a major part of the cost of the finished part.


ISO P Steel
P
ISO M Stainless Steel
M
ISO K Cast Iron
K
ISO N Non-ferrous Metals
N
ISO S Heat Resistant Alloy
S
ISO H Hardened Steel
H

Machinability is influenced by the following variables:

Machine Variables:

Machine variables (like power, torque, accuracy and rigidity) indirectly affect the machinability. The machine should be rigid and have sufficient power to withstand the induced cutting forces and to minimise deflections.

Tool Variables:

These include tool material, tool geometry, and the nature of engagement of tool with the work. The cutting tool has to be optimised to obtain a reasonable value of tool life and remove maximum material. Proper tool geometry is essential for efficient machining and it is chosen depending on the work material and machining conditions.

Surface finish is greatly influenced by the tool geometry. Tool rigidity affects tool life, surface finish and dimensional accuracy.

Cutting Condition:

Cutting speed has the greatest influence on tool life. The surface finish, normally, is improved by increase in the cutting speed, due to continuous reduction of the built-up edge. Dimensions of cut and cutting fluids also influence tool life.

Work Material Variables:

Hardness, tensile strength, chemical composition, microstructure and method of production of work material have influence on machinability.

Experience has shown that a correlation exists between the basic physical properties of the metals and their machinability.

Machinability decreases with increase in tensile strength. This property together with hardness is probably a good criterion of machinability.

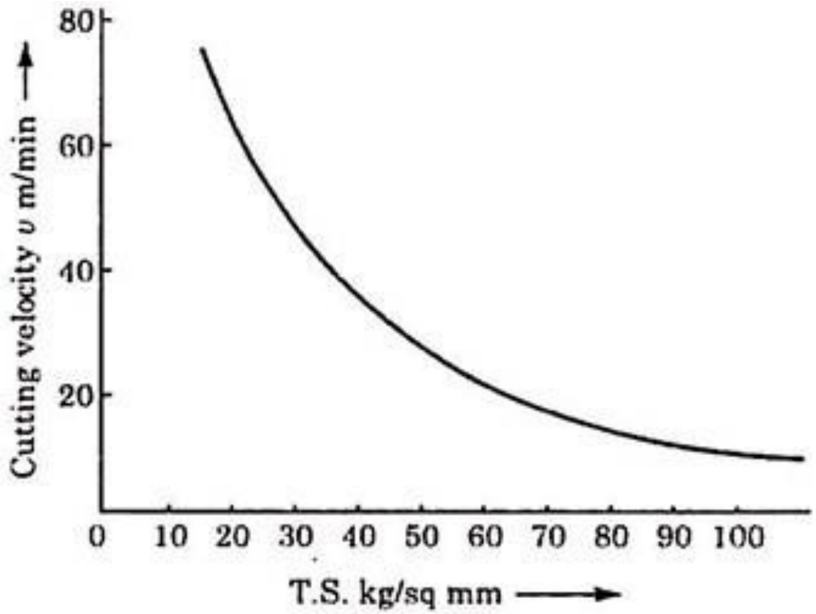


Fig. 24.1. The curve is drawn for feed = 1 mm/rev. and depth of cut = 4 mm.

(In the descending order)

(1)	Magnesium alloys	Excellent
(2)	Bearing bronze	Excellent
(3)	Aluminium alloys (80% Cu), Duralumin etc.	Excellent
(4)	Zinc alloys	Good
(5)	Free cutting sheet brass	Good
(6)	Red brass or low brass or gliding metal or gliding brass	Good
(7)	Gun metal (Cu 88% ; Sn 10% ; Zn 2%)	Good
(8)	Silicon bronze ; Leaded phosphor bronze, Manganese bronze	Good
(9)	S.G. cast iron	Good
(10)	Malleable cast iron	Good
(11)	Gray cast iron	Good
(12)	Yellow brass (cartridge brass) [70% Cu, 30% Zn]	Good
(13)	Leaded steel or free cutting steel	Good
(14)	Sulphur bearing steel	Good
(15)	Cu-Al alloys	Good
(16)	Low carbon steels	Fair
(17)	Cast copper	Fair
(18)	Free cutting 12% Cr iron	Fair
(19)	Nickel (annealed)	Fair
(20)	Low alloy steels	Fair
(21)	Ingnot iron	Poor
(22)	Wrought iron	Poor
(23)	Free-cutting 18-8 stainless steel	Poor
(24)	High speed steel	Very poor
(25)	18-8 stainless steel	Very poor
(26)	Monel metal (Ni-base Ni-Cu alloys)	Very poor
(27)	White cast iron	Not Machinable
(28)	Stellite (15% W ; 30% Cr ; 1 to 3% C and 45 to 55% Co)	Not Machinable
(29)	Sintered carbides	Not Machinable

Carbon steels nearly always have better machinability than alloy steels of comparable carbon content and hardness.

C content has a dominant effect on the machinability of C steels, chiefly because it governs strength, hardness, and ductility.

Low carbon steels have low hardness and high ductility with the tendency forming built-up edge (BUE) adhered to the cutting tool strongly, which leads to reducing tool life and poor surface finish. Its machining behavior can be improved by increasing strength and reducing ductility through cold-drawing. Higher carbon content improves the machinability in such a way that hardness is increased moderately and ductility decreased.

Using high-speed steel tools to machine steels with hardness higher than 300 HV is very difficult. Carbide tools can be used to cut steels with higher hardness. But when the hardness exceeds 500 HV, carbide tool life becomes very short and permissible cutting speeds are very low. To cut hardened steels, the cutting tools must retain their hardness and yield strength at the elevated cutting temperatures. Ceramic tools can be used to cut steels with hardness of 600–650 HV. Using cubic boron nitride (CBN) tools can machine fully hardened steels with large material removal rate and long tool life. But CBN tool costs also very high.

Stainless steels are considered to be more difficult to machine than carbon steels due to high tensile strength, high ductility, high work-hardening rate, low thermal conductivity, and abrasive character, which lead to higher tool wear rate, difficulties with chip breakability, and poor surfacefinish.

Austenitic stainless steels are strongly work hardening. A built-up edge is formed during cutting of austenitic stainless steels even in a relatively lower cutting speed than cutting of carbon steels. They bond very strongly to the cutting steel, and chips often remain stuck to the tool, causing the tool fragment once the chip broke away.

Typically, austenitic stainless steels are more difficult to machine than ferritic and martensitic stainless steels. Duplex stainless steel is similar to austenitic stainless steel but harder to machine due to its high annealed strength. Generally, TiN–TiCN-coated carbides are recommended for machining of stainless steels using lower cutting speeds and material removal rates than carbon steels, larger depth of cut than work-hardening layer thickness, and flush coolant.

Low-carbon steels containing less than 0.15% C are low in strength in the annealed condition; they machine poorly because they are soft and gummy and adhere to the cutting tools.

Steels in the 0.15 to 0.3% C range are usually machined satisfactorily in the as-rolled, as-forged, annealed, or normalized condition with a predominantly pearlitic structure.

The medium-carbon grades, containing up to about 0.55% C, machine best if an annealing treatment that produces a mixture of lamellar pearlite and spheroidite is utilized. If the structure is not partially spheroidized, the strength and hardness may be too high for optimum machinability.

For steels with C content higher than about 0.55%, a completely spheroidized structure is preferred. Hardened and tempered structures are generally not desired for machining. Both tool life and production rate are adversely affected by increases in carbon content.

The addition of **lead** (0.15 to 0.35% Pb) to steels is a means of increasing the machinability of the steels.

Because lead is insoluble, or nearly so, in molten steel, a fine dispersion of lead particles develops as the steel solidifies.

It is generally believed that lead has a minimal effect on the yield or ultimate strength, ductility, or fatigue properties of steels at room temperature and moderate strength levels.

Environmental considerations may restrict the manufacture or use of leaded steels.

Leaded steels cost about 5% more than similar nonleaded compositions.

In carbon steels, the **sulfur** content is ordinarily restricted to a maximum of 0.05%.

But machinability is enhanced when sulfur is added.

Sulfur combines with manganese to form manganese sulfides, which help the chip to break and improve surface finish

The most common range of sulfur content in resulfurized steels is 0.08 to 0.13%, but some grades permit sulfur content as high as 0.35

Sulfide inclusions, depending on their size, shape, and orientation, improve machining by causing the formation of a broken chip instead of a stringy or continuous chip and by providing a built-in lubricant that prevents the chips from sticking to the tool and undermining the cutting edge.

Phosphorus, as well as sulfur, is often added to improve the machining characteristics of low-carbon steels.
The phosphorus limits are 0.07 to 0.12%. The limits are set because phosphorus, like carbon, increases the hardness and strength of the steel.
Consequently, excessive phosphorus contents impair machining characteristics and some other properties of steel. Phosphorus is soluble in iron and increases the strength of ferrite, resulting in harder but brittle chips, an effect that promotes chip breaking in cutting operations. The phosphorus helps to avoid the formation of long, stringy chips in some operations and may result in a better surface finish.

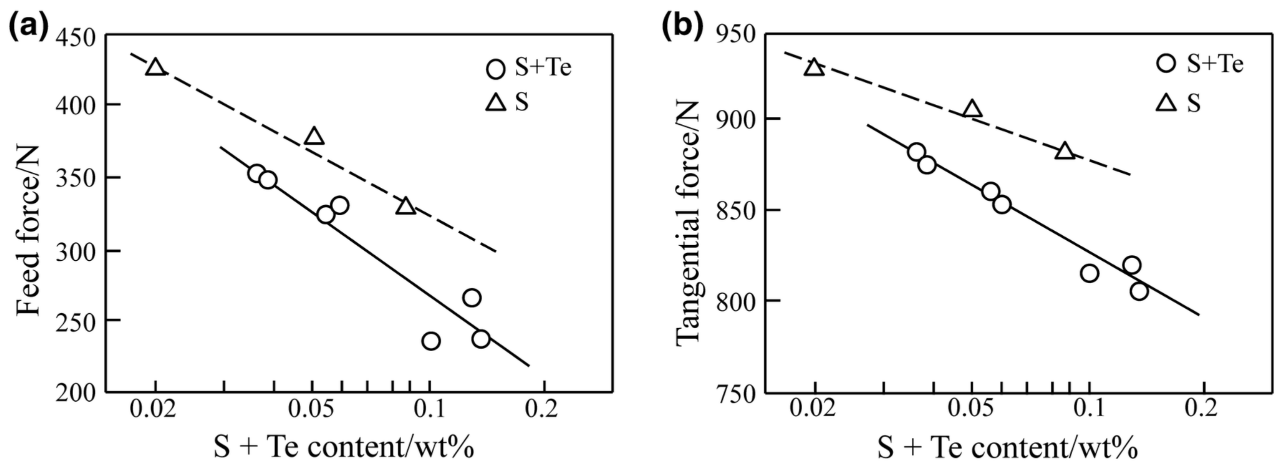
Nitrogen. Nitrogen adversely affected the life of HSS tools used for turning and form cutting.

Selenium and tellurium additions improve machinability but are not available in standard grades of steel. These additions are expensive (selenium treatment increases the cost of steel by about 15%).
Typical percentages of either element would be 0.04 or 0.05%.

Both elements seem to exert beneficial effects by promoting the retention of globular-shaped sulfide-type inclusions.

For the same reason, they are considered to have a less deleterious effect than sulfur on mechanical properties.

0.042% Te quadrupled the number of parts made between tool changes and improved the surface finish.



Se is even more effective than Te in improving the machinability of steels, particularly alloy steels.

Calcium additions improve the machining characteristics of steels fully deoxidized with aluminum.
The cost of the special treatment is relatively modest.

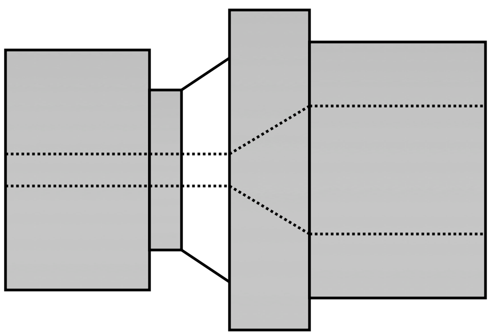
Steels made by aluminum deoxidation practices ordinarily contain small inclusions of aluminum silicate in quantities essentially independent of the amount of aluminum added to the steel. The inclusions are often assumed to be alumina, and the poorer machinability of aluminum-killed steels, compared to steels deoxidized with silicon, is often attributed to the supposedly abrasive effects of the inclusions.

Calcium additions result in larger inclusions consisting of calcium-aluminum silicates, these inclusions to be softer and less abrasive

Tool life and cutting speed can be related by the equation:

$V_c \; T^n = C_t$ (Taylor equation)

where V_c is the cutting speed, T is the tool life, and n, C_t are empirical constants that reflect the cutting conditions under which the tests were made and the machinability of the material (C_t Taylor's equation)



Machinability test piece